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The state-of-the-art approach in assuring the functionality of pre-moulded joints for HVDC cable systems is via prequalification (PQ) and type testing (TT) as defined in IEC 62895. These test regimes are performed on full-scale cables and joints, which means they accurately reflect the in-service conditions that the cable system has to withstand during its lifetime. On the other hand, PQ and type tests involve a high financial and time outlay, so they are usually preceded by elaborate design phases development tests performed on laboratory samples. A major challenge is therefore the selection of suitable development tests which, on the one hand, meet the requirement for the lowest possible complexity and, on the other hand, represent the critical chemical and physical phenomena at the interface as realistically as possible. A detailed understanding of the physics of the interfaces is crucial to meet this challenge.
Based on years of operating experience with pre-moulded joints in HVAC cable systems, some macroscopic factors can be identified that are also significant during operation with DC voltage :

- Cavities between cable and joint insulation as a result of high surface roughness, low interfacial contact pressure (either immediately after installation in case of improper sizing, or after several thermal cycles in case of relaxation of the joint base material), or drying out of the lubricant used during joint installation
- Electrical field distribution at the interface based on the effective electrical conductivity of the cable and joint insulation material, which is in turn temperature and field dependent, such that the field distribution varies for different load scenarios
- Quality of workmanship and installation of the cable joint ; examples for improper installation include incomplete removal of the outer semicon from the cable insulation, misplacing of the joint such that the edge of the outer semicon and conductor connector are not properly shielded (in case of geometric field grading), scratching the cable insulation etc.

The aforementioned factors, as well as their impact on cable system performance, are described in TB 210 and TB 476. Note that the impact might be different for HVDC cable joints compared to HVAC cable joints – it is therefore required to adapt existing benchmarks.
The macroscopic factors and their impact on the interface may be studied experimentally, e.g. with small scale model cables and joints, or by simulation using finite element analysis (FEA). Provided that the geometry is properly implemented and that the correct material parameters are used as an input, FEA is suitable for accurately modeling the joint in its entirety. Standards such as IEC 62631 provide the determination of these input parameters with high repeatability and reproducibility. However, simulating the entire joint makes it difficult to account for microscopic effects in reasonable computation time.
It is well-known that these microscopic effects, namely space and surface charge, have a major effect on the integrity of polymeric insulation systems. They are considered both cause and effect of ageing and might lead to impermissible local field enhancements if not properly controlled.
Methods for both experimental and simulative studies of space charge have been developed and tested by the scientific community, and recommendations for space charge measurements are given by IEEE Standard 1732. Still, these highly sensitive measurement techniques are limited when it comes to investigating full-scale cable joints, especially for the currently established voltage levels of 525 kV and above. What’s more, the commonly used bipolar charge transport model (BCTM) for calculating the space charge distribution in polymeric insulation material requires a large set of input parameters that are difficult or even impossible to measure directly. The parametrization of the model is hence challenging and can only be done via parameter fitting, optimizing the consistency between measured and calculated space charge distribution. This process needs to be repeatedly performed over time to properly assess the development of the space charge distribution in HVDC cable joints during their lifetime.
Both the macroscopic and the microscopic approach have been used for many years and are proven to work within their limits, such that a good correlation between measurement and simulation can be achieved. At this point, the next step is bridging the gap between the full-size component and the small-scale laboratory samples. This question is currently discussed within JWG B1/D1.75, which has been established in early 2020.
Both approaches discussed before offer added value and support in achieving a complete picture of the phenomena occurring in HVDC cable joints, so they should continue to be used side by side and their results should be linked. In order to do this, it is necessary to establish enlargement laws for extrapolating results achieved with material samples to complete cable joints. In order to properly design and select experimental environments and methods for laboratory tests, the boundary conditions for testing material samples must be derived based on the condition within the cable joint. A co-simulation might be a viable approach to combine the FEA and BCTM.